The Phoenix Series of Liquefied Natural Gas Pool Fires

Figure 1: LNG cargo carrier entering Boston harbor for offload.

Figure 2: Large scale LNG pool fire experimental site.

Large-scale experiments enable researchers to examine big spills that would occur from LNG tankers

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Due to the growing demand for natural gas nationwide, the number of liquefied natural gas (LNG) tanker deliveries to U.S. ports (Figure 1) is expected to increase, thus raising concerns about accidental spills or other events. The risks and hazards of a LNG spill will vary depending on its size, the environmental conditions, and the harbor. Risks include not only harm to nearby people, but also significant property damage and economic impact due to long-term interruptions in the LNG supply. Therefore, methods to ensure the security of LNG terminals and shipments in the event of an incident are critical from both public safety and property perspectives.

Much progress has been made in LNG threat consequence and vulnerability assessment. A general approach to risk evaluation has been developed, and is used as a basis in site-specific risk assessments. However, there are significant knowledge gaps in the science of very large-scale LNG pool fires. These gaps create serious uncertainties that may either under- or over-estimate latent hazards. Generally, the surface emissive power of a pool fire is a function of pool size and will increase to reach a maximum value then decrease to reach a limiting value with increasing diameter. For LNG, the limiting power is uncertain. To fill the knowledge gaps and reduce uncertainty, it became necessary to leverage Sandia's considerable expertise in thermal science to stage very large (> 25-m diameter) LNG pool fires that would surpass by a factor of ten anything that had been attempted previously.

To accomplish this task, the Sandia team came up with a simple, low-cost concept of excavating a shallow 120-m diameter pool for the water, and then using the soil to create a deep, insulated 310,000 gallon reservoir to hold the LNG needed for the test (Figure 2). Concrete pipes from the center of the reservoir transported the LNG to the center of the water pool (Figure 3). A simple removable plug allowed gravity to control the flow rate (Figure 4). The considerable safety issues were reservoir integrity, thermal hazards (from cryogenic to extreme heat), asphyxiation, explosion, drowning, and aviation traffic. An advanced three-dimensional transport simulation was used to evaluate both the thermal performance of the reservoir and components, the

transport of gaseous boil-off during the cool-down process, and the design of the diffuser in the middle of the pool used to translate the linear momentum of the LNG in the pipes to a radially-spreading pool. Data was captured via cameras (gyroscopically stabilized and suspended from helicopters), spectroscopic diagnostics, and heat flux sensors.

Experiments were completed on two LNG spills, with diameters of 25 m and 85 m. Datasets will now allow model development and validation for extrapolation to a scale expected for a spill (300-500 m). The data had unexpected results in that the fire diameter was smaller than the spreading LNG pool diameter (Figure 5). Previous studies with stagnant pools in pans had resulted in fires the same size as the pool. However, in all such studies, the pans have edges that can result in flame stabilization that would not be available on the open water. The data further showed that, in both very light and significant cross-winds, the flame will stabilize on objects projecting out of the water, suggesting that the ship itself will act as a flame holder.

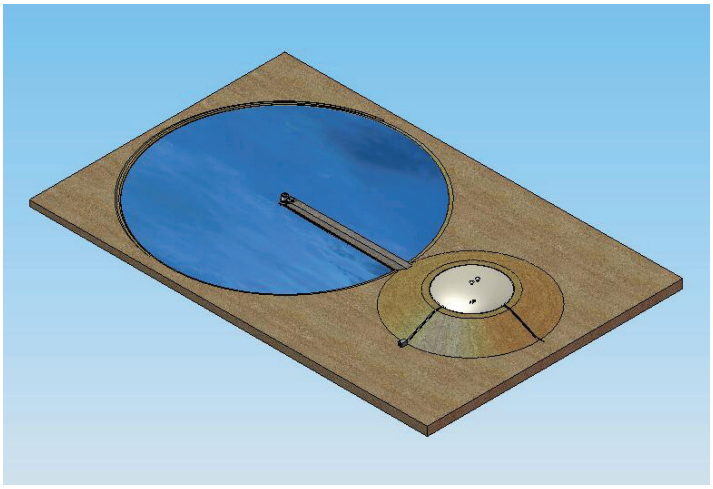

Figure 3: Schematic of test facility showing LNG reservoir (right), and concrete piping going to the center of the pool.

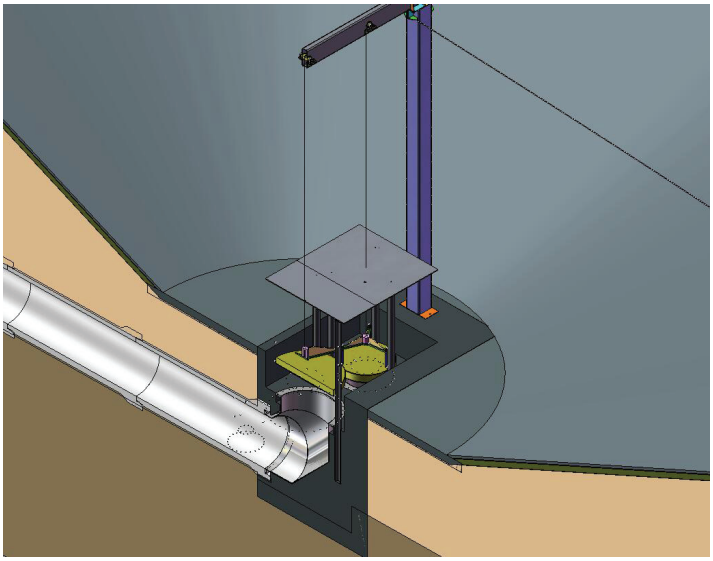

Figure 4: Schematic of gravity fed flow and removable plug in center of pool.

Figure 5: Image of 85-m pool fire that shows flames not extending across spreading (white area) LNG pool.

Sandia National Laboratories

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